Dimensional Accuracy of Acrylic Resin Maxillary Denture Base Polymerized by a New Injection Pressing Method

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The purpose of this study was to confirm the dimensional accuracy of a newly developed injection pressing method for resin polymerization by making use of the internal electric resistance of resin to determine the optimal timing for resin injection. A new injection pressing polymerization pot with a built-in system to measure the internal electric resistance of resin was used for resin polymerization. Fluid-type resin was injected into the mold of a maxillary complete denture base under nine different conditions: three different timings for resin injection according to the electric resistance of resin dough (early stage: 11 MΩ; intermediate stage: 16 MΩ; final stage: 21 MΩ) and three different motor powers for resin injection (2000 N, 4000 N, and 6000 N). In the best polymerization condition (injected during the early stage of resin dough under a motor power of 6000 N), the adaptation of the denture base showed a statistically significant improvement compared with the conventional pouring method.

Key words: Denture base resin, Polymerization, Injection pressing method

INTRODUCTION

Acrylic resin is still widely used as removable denture base material. To fabricate a denture base with an accurate fit to oral mucosa, there must be good control over the three factors that affect dimensional stability: influence of cast material, shape of palate, and polymerization process. Several techniques are utilized in resin polymerization, such as heat polymerization method, pouring method, injection pressing method, and microwave-activated polymerization method. Improvements have been made in each method to strive towards a system with high accuracy and reliability.

The pouring method of denture base resin was developed in the 1960s and has been one of the most popular polymerization techniques because of two merits. It is simple to use and it offers better dimensional accuracy than the heat polymerization method. However, the pouring method is not without shortcomings. It is difficult to determine the optimal timing for resin injection as the latter depends on the temperature of the room in which injection is performed. Another problem is that polymerization shrinkage tends to localize on the polished surface of the denture base. These problems thus highlight the need to improve the polymerization method developed to-date.

The present study attempts to provide a new polymerization system. By making use of the internal electric resistance of resin, it can inject fluid-type resin at an optimal timing. We then compared this system with the conventional pour resin method with respect to the dimensional accuracy of the maxillary denture base.

MATERIALS AND METHODS

In this study, Palapress vario© (Heraeus Kulzer, Wehrheim, Germany) was used as the fluid-type resin material. In our preliminary experiment, when the liquid-powder weight ratio was constant, there was an observed relationship between the electric resistance of the fluid-type resin and its macroscopic change. When the liquid-powder weight ratio was 0.5, the electric resistance was 2-4 MΩ for the pasty period immediately after mixing, 5-7 MΩ for the thick malt syrup-like period, 8-10 MΩ for the stringy period, 11-29 MΩ for the resin dough period, and 30 MΩ or higher for the rubber-like period.

The newly developed injection pressing polymerization pot (Intopress III©, Tohan Kiden Co., Higashiosaka, Japan) (Fig. 1) features an injection pressing motor power that varies according to the electric current. This injection pressing polymerization pot can also time the resin injection such that the latter starts automatically according to a predetermined electric resistance. In other words, when the built-in electric resistance meter (ohmmeter) detects the predetermined/pre-specified resistance, resin injection under pressure will automatically start and pressure will be kept constant.

To evaluate the adaptation of denture base, a cast from the rubber mold of a maxillary edentulous jaw model (Nissin Co., Kyoto, Japan) was fabricated using improved type IV dental stone (New Fuji Rock,
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Fig. 1 Newly developed polymerization pot (Intopress III, Tohan Kiden Co., Higashi-osaka, Japan).

GC Co., Tokyo, Japan) mixed with 20% of water (in weight ratio). Then, a base plate having a 1.5-mm thick wax pattern was fabricated on the cast using paraffin wax (Paraffin Wax, GC Co., Tokyo, Japan), and was subsequently invested in a lower metal flask using normal dental plaster. Sprue wax 7 mm in diameter (Utility Wax, GC Co., Tokyo, Japan) was attached to the center of the posterior rim of the wax pattern. The secondary investment was made using improved stone with a low expansion rate (setting expansion rate: 0.09%) (Plastone L, GC Co., Tokyo, Japan) with water-powder weight at a ratio of 0.26. After the tertiary investment was made using dental stone (Dental Gypsum, Maruishi Gypsum Co., Osaka, Japan) and the stone was set, wax elimination was performed using boiling water. After the cast and investment stone in the flask were bench-cooled to room temperature and dried, a resin-separating medium (Isolar, Heraeus Kulzer, Wehrheim, Germany) was used to line the surface of the cast.

To investigate the injection pressing method, five samples were made using the injection pressing polymerization pot and fluid-type resin (Palapress vario) mixed in a liquid-powder weight ratio of 0.5 under the nine conditions shown in Table 1. The timing for injection as determined by electric resistance was selected from one of the following three conditions: early stage of resin dough (11 MΩ), intermediate stage of resin dough (16 MΩ), and final stage of resin dough (21 MΩ). The motor power condition was selected from the following three conditions: 2000 N, 4000 N, and 6000 N. The resin was polymerized under constant pressure (as maintained by the motor), and additional polymerization was performed in water at 55°C for 30 minutes according to manufacturer’s instructions. The pressure was maintained until the resin in the flask became rubber-like (as indicated by the internal electric resistance reading).

To prepare for the conventional pouring method, the wax pattern had a primary investment of dental stone (Dental Gypsum, Maruishi Gypsum Co., Osaka, Japan) in a rubber flask, to which sprue and vent wax (Utility Wax, GC Co., Tokyo, Japan) were attached. Subsequently, the secondary investment of improved stone (Plastone L, GC Co., Tokyo, Japan) and the tertiary investment of dental plaster were made. Then wax was eliminated using boiling water. After mixing the powder and liquid (Palapress vario) at a liquid to powder weight ratio of 0.7 for 30 seconds, the pasty resin was poured continuously from the sprue hole. Polymerization using the pressing polymerization pot (Intopress II, Tohan Kiden Co., Higashi-osaka, Japan) was performed for 15 minutes under a pressure of 0.25 MPa in water at 55°C. Five samples were produced.

After placing the polymerized sample in water at room temperature for 48 hours, the sample denture base was carefully removed from the cast and then placed back onto the cast under a fixed load (3 N) to ensure adaptation. The sample together with the cast were embedded in stone for investment at a low-setting expansion rate (Advastone, GC Co., Tokyo, Japan) (setting expansion rate: 0.09%) to avoid rebound. The embedded cast was then cut using a low-speed precision cutting machine (Isomet, Buehler Co.,

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Results

The gap between the denture base and the cast in the injection pressing method under each condition is shown in Table 2 and in Figs. 3 to 5. For the injection pressing method, the gap was minimum at all measurement points under 6000 N motor power. In particular, injection at the early stage of resin dough under 6000 N motor power yielded the following results:

- For this condition, the gap was significantly smaller as compared to other conditions (p < 0.05).
- Adaptation was significantly improved at all measurement points as compared to the conventional pouring method (p < 0.01).
- At the center of the palate, the sample produced by conventional pouring method had a gap of 205 ± 17 µm, whereas that produced by injection pressing method under this condition had a gap of 49 ± 5 µm, which was significantly smaller (Fig. 3).
- Similarly, adaptation was significantly improved at the marginal area and the middle of the residual ridge (Figs. 4 and 5).
DISCUSSION

Several studies have been conducted concerning adaptation of the denture base, and various methods have been used to evaluate adaptation. These methods include macroscopic evaluation of denture base adaptation using paste material cast directly in the oral cavity\(^1\), evaluation of the weight of silicone fitness test material\(^16,17\), and measurement of the rise or linear shrinkage of the denture base using a plaster model or dye\(^18,20-26\). In the present study, we measured the space between the denture base and the model after placing the denture back onto the cast. In addition, in a preliminary experiment, we obtained the minimum load required to place the denture back onto the model without deformation, and 3 N was selected as the loading condition\(^17\). Thus far, base plate type\(^19,20,25,26\) and denture type using arranged artificial teeth\(^16,7,21-24,26\) have been used for samples. Factors affecting adaptation, such as the presence of arranged artificial teeth\(^25\) or sample thickness\(^18\), were considered. In the present study, the base plate sample on the maxillary cast had a uniform thickness. On the other hand, a frontal section 14 mm anterior to the posterior edge, at which the width of the model was maximum, was selected for measuring the space between the denture base and the cast. This is because the wider the cast, the larger the dimensional change\(^26\).

In the present study, nine conditions were set based on the following parameters: three injection timings (early stage of resin dough, intermediate stage of resin dough, and final stage of resin dough) and three motor power conditions (2000 N, 4000 N, and 6000 N). The denture bases were made under these nine conditions, and adaptation was evaluated in each case. The results showed that the gap between the denture base and the cast was significantly smaller when resin was injected at the early stage of resin dough, as compared to the other stages. In addition, the gap was significantly smaller under the motor power of 6000 N, as compared to the other motor power conditions. Therefore, adaptation was best when resin was injected at the early stage of resin dough using a motor power of 6000 N.

In the preliminary experiment, the highest inner pressure — at a maximum value of 3.35 MPa — was observed for the above-mentioned optimum condition, as compared to the other polymerization conditions. Anderson et al\(^13\) and Huggett et al\(^14\) reported that besides being enlarged by monomer molecules, the polymer became compacted and the structure uniform — thus effectively offsetting polymerization shrinkage and improving adaptation as a result. Similarly, in the present experiment, polymerization shrinkage might have been effectively offset by injection pressing — which suggests that proper setting of the inner pressure is important in order to improve adaptation of the denture base. Jerolimov et al\(^27\) reported that linear shrinkage became smaller if the resin had a reduced liquid-powder ratio. In the context of this investigation, the injection pressing method did not provide any means for pouring pasty resin. Instead, resin was injected under pressure via motor power so that the amount of polymer could be increased to equal that of the heat-curing resin. Consequently, reduced shrinkage may be related to improved adaptation. Polymerization shrinkage is believed to be effectively offset by improving the liquid-powder ratio as well as by the effect of continuous pressing, which leads to a significant improvement in adaptation, as compared to the conventional method.

CONCLUSION

A denture base was made on a plaster cast using the injection pressing polymerization pot which made use
of electric resistance to set the timing for resin injection. Based on three different timings for resin injection (i.e., early, intermediate, or latter stage of resin dough) and three different motor power conditions (i.e., 2000 N, 4000 N, or 6000 N), nine conditions were set. The gap between the denture base and the cast was measured in order to evaluate adaptation, and this gap was then compared with that produced by conventional pouring method. By selecting the proper timing and motor power, the injection pressing method produced a denture base whose adaptation was significantly improved, as compared to the conventional pouring method (p<0.01).

Based on the results of the present study, the proposed injection pressing method — which made use of electric resistance of fluid-type resin — significantly improved adaptation of the denture base as compared to that produced by conventional method. In this respect, this polymerization method can be considered to be clinically effective.

REFERENCES